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13. ABSTRACT (Maximum 200 words)

A large amount of work, of high quality, was produced under this grant. The PI gave invited talks at ten technical meetings and conferences, was elected to the membership of the Third World Academy of Science, had four papers published, with six more being accepted for publication. Four papers have been submitted for publication and eight papers are in final preparation.

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Final Report on AFOSR Grant #91-0031

MULTIVARIATE PROBLEMS OF STATISTICS, COMBINATORICS, RELIABILITY, AND SIGNAL PROCESSING

Principal Investigator: Jagdish N. Srivastava
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Grant Period: November 1, 1990 - October 31, 1992

Although, unlike in previous years, the grant was for only two months per year, a relatively large amount of work was accomplished. The quality of the work also remained very high, as usual.

Since the grant has now been terminated, we are presenting this final report. At this time, the Principal Investigator would like to thank the Technical Monitor for his foresight in encouraging and approving this research project. Thanks are also due to the Director of the Mathematical Sciences Division for allowing this research to be done.

These two years are the last two years for the Principal Investigator of a series of grants which originally began in 1959. During this long period of several decades, important research which made history, has been accomplished. The Principal Investigator would like to thank the Air Force for supporting this research. As has been shown time and again, many times, the research done under this series of grants was an example of the high quality of research work that the Air Force supported in this very important field. FUTURE HISTORIANS OF SCIENCE LOOKING AT ALL THE WORK ACCOMPLISHED UNDER THIS SERIES OF GRANTS OVER THIS LONG PERIOD, WILL SURELY CONSIDER THE PEOPLE RESPONSIBLE FOR DECIDING ON GRANTS IN THE AIR FORCE (DURING 1959-92) TO HAVE DONE AN EXCELLENT JOB FOR THE AIR FORCE.

The report will be divided into several sections, which are self explanatory.

I. Conferences and visits

During the approximate period of two years under review, Srivastava visited, among others, the following places.

1. He gave an invited talk in the field of Linear Models and Multivariate Analysis, in the International Conference on Mathematical Statistics at Tampere, Finland, August 1990.

2. In June 1991, he gave an invited talk at the International Conference on Reliability, held at the University of Missouri.
3. In August 1991, he attended the meeting of the American Statistical Association in Atlanta.
4. In September 1991, he attended the meeting of the International Statistical Institute in Cairo Egypt.
5. In September 1991, he gave an invited talk at the University of New Mexico, Albuquerque.
6. In October 1991, he participated in the Army Research Conference held at Vicksburg, Mississippi.
7. In October 1991, he gave an invited talk in Combinatorial Mathematics at Xavier University, New Orleans.
8. In October 1991, he gave an invited talk in the Biometrics Department at the University of Louisiana Medical Center.
9. In November 1991, he gave an invited talk at Bowling Green State University, Ohio, in the field of Multivariate Analysis.
10. In December 1991, he gave an invited talk at the Third Pacific Area Conference in Mathematical Statistics, held in Tokyo. The field was Reliability.
11. In December 1991, he gave and invited talk at Hitotsubashi University, Tokyo in Multivariate Analysis.
12. In December 1991, he gave an invited talk at the Institute of Natural Sciences in Kurashiki, Japan in Design Theory.
13. In December 1991, he gave a special invited address at the First International Triennial Symposium in Statistics, at Calcutta University, India.
14. In January 1992, he gave an invited talk at the University of Lucknow, India.
15. In January 1992, he briefly visited Thammasat University, in Bangkok, Thailand.
16. In May 1992, he gave an invited talk at the prestigious conference on "Future Directions in Multivariate Analysis", held at Pennsylvania State University. This was a part of the Around the World Multivariate Analysis Conference, of 1992.
17. In June 1992, Srivastava participated in the International Conference on Decision Theory at Purdue University.

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18. In August 1992, he presented papers at the meeting of the American Statistical Association, and Institute of Mathematical Statistics, in Boston.

II. Honors Received

1. In August 1990, Srivastava was elected to the Fellowship of the Institute of Combinatorics and Its Applications.
2. In February 1992, Srivastava was elected to the Membership of the Third World Academy of Science.

III. Publications

Papers Published

1. (with D. Throop) "Orthogonal arrays obtained from partial pencils in Euclidean n -space." Linear Algebra and Its Applications, 127, 283-3000, 1990.
2. "Some basic issues in statistical design theory with special reference to the theory of response surfaces." JSPI, 24, 415-435, 1990.
3. (with S. Arora) "Minimal resolution 3.1 designs for the 2^4 experiment." Coding Theory and Design Theory, Part II, (Springer Verlag) (Ed. D.K. Ray Chaudhari) (1990), pages 336-361.
4. "Modern factorial design theory for experimenters and Statisticians." Design and Analysis of Experiments with Applications to Physical and Engineering Sciences. (Marcel Dekker). (Ed. S. Ghosh) (1990) pages 311-406.
5. (with R. Hveberg) "Sequential factorial probing design for identifying and estimating nonnegligible factorial effects for the 2^m experiment." JSPI, 30 (1992), 141-162.
6. (with S. Arora) "A general series of resolution 3.2 designs for the 2^m experiment." Discrete Math., 98, 35-56.
7. (with Z. Ouyang) "Sampling theory using experimental design concepts." IMS Lecture Notes Volume. (Ed. M. Ghosh and P.K. Pathak) (Springer Verlag).
8. (with Z. Ouyang) "Some properties of a certain general estimator in finite population sampling." JSPI, (1992), 31, 199-218.

IV. Papers accepted for publication

9. "A 2^8 factorial search design with good revealing power" (17 typed pages). To appear in Sankhya.

10. (with Z. Ouyang and H.T. Schreuder) "A general ratio estimator, and its application to regression model sampling in forestry." (29 typed pages). To appear in Ann. Inst. Stat. Math.
11. (with Z. Ouyang) "Studies on the general estimator in sampling theory, based on the sample weight function." To appear in Sankhya.
12. "Nonadditivity in row-column designs." To appear in Jour. Comb., Inf., Syst., Sc.
13. "Multivariate analysis with few or incomplete observations." (37 typed pages). To appear in Proceedings of Conference on Future Directions in Multivariate Analysis, held at Pennsylvania State University, May 1992.
14. "Some basic contributions to the theory of comparative life testing experiments." To appear in Proceedings of International Conference on Reliability, held at Columbia, Missouri, June 1991.
- V. Papers submitted
15. (with Z. Ouyang) "Minimax and admissibility properties of balanced proportional array strategy and strongly weight balanced strategy." (18 typed pages).
16. (with M. Salgado) "Construction of orthogonal and balanced arrays from orthogonal arrays involving a larger number of symbols."
17. "A new mathematical space with applications to statistical experimental design."
18. "Certain diophantine equations useful in orthogonal designs, coding theory, and signal processing."
- VI. Papers whose final draft is ready
19. "Some basic results in the interface of sampling and design theory."
- VII. Papers whose first draft is ready
20. (with A. Khodadadi) "Efficient modifications of censoring procedures of Type I for life testing." (23 typed pages).
21. (with J. Li) "Certain classes of orthogonal 2^m factorial designs of intermediate resolution." (31 typed pages).
22. (with J. Li) "Some optimal designs of the parallel flats type for the 2^m case." (25 typed pages).
23. (with J. Li) "Some probing designs for the 2^4 case." (25 typed pages).
24. (with S. Ghosh) Truly orthogonal main effect plans. (16 typed pages).

Papers under preparation

25. On the probability of correct identification of the nonnegligible parameters in search linear models."
26. "Some basic connections between design theory and signal processing."

VIII. Comments on the publications

Paper #1 gives a neat result in the field of orthogonal arrays. In the 1940's, Bose obtained the famous result that by solving certain kinds of linear equations over a finite field, we can generate an orthogonal array. This important paper generalizes that result.

Paper #2 shows how to improve the existing theory of response surface designs. It discusses the philosophy of experiments of this type, and shows that the kind of work that Box and others have done in response to surface theory can be greatly improved.

Paper #3 is a long paper where we establish the minimal size designs for the 2^k experiment. This paper should go a long ways towards giving the theoretical basis for further work in search designs.

The next paper #4 is a very long review paper meant for introducing the factorial design theory as it currently stands. It contains a formulation of the subject which is found in no text anywhere. It is also seen that this is the only realistic formulation.

The first paper (#5) is a new development in the field of factorial designs where we considered the sequential case. It is one of the very few papers existing on the subject in the literature. The idea here is to find ways by which we can identify the vector of nonnegligible factorial effects. This corresponds to the realistic formulation of the theory of factorial experiments. Many authors who work in the field of the application of experimental design to industry, and many others, often make the unrealistic assumption that they know the set of factorial effects which are nonnegligible, in advance. Indeed, worse than that, many authors assume that only the main effects are not nonnegligible; this is quite unrealistic and leads to large errors which go undetected.

The next paper (#6) is a long and complex analysis of some problems in search designs, and establishes many basic results in this subject, which should be important for future research.

Paper #7, as is clear from the title, studies the connection between sampling theory and experimental design.

Paper #8 is a contribution to sampling theory, which should have an enormous effect on the subject in the coming years. Basically, it is an outgrowth of the work of the Principal Investigator in 1985, where a new, very general and very powerful estimator was introduced. The work in this paper shows that the new estimators are at the top of the subject of sampling. We claim that this is probably the best research done in the subject in decades. If someone wishes to challenge this claim, we are willing to have a public discussion on the topic.

Paper #9 is a contribution to the situation where we do not satisfy the strong condition needed for search designs, but where we do satisfy weaker conditions. These weaker conditions make the design quite realistic for situations where we do have a slight amount of extra information available on the parameters.

Paper #10 deals with certain developments on the estimator of Srivastava, which was introduced in 1985, and further developed in paper #4. This paper considers modification of that estimator suitable for forestry.

In paper #11, we show that many estimators that are extremely well known, and named after their discoverers, are special cases of the estimator of Srivastava.

Paper #12, is a precursor to another paper which will come in the year 1993-94. Here, we show that there are important defects in the theory of Latin Square Designs, arising out of nonadditivity of the effects of nuisance factors.

Paper #13 is a review paper summarizing the important work that has been done during the past three decades in the field of multivariate analysis with few or missing observations.

Paper #14 is also a review paper reviewing the important breakthroughs made by Srivastava in the field of reliability during the past several years.

Paper #15 is concerned with properties of the estimator of Srivastava in certain situations which are of interest in the theoretical aspects of statistical inference.

Paper #16 shows how to construct orthogonal arrays and balanced arrays from orthogonal arrays.

Paper #17 is an important new development in the field of statistical experimental design. A new mathematical space has been introduced. We expect a large reward from the future applications of this work.

Paper #18 obtains certain necessary conditions which should be useful for combinatorial mathematicians who work on combinatorial arrays in general, and their applications.

Paper #19 further connects the theory of sampling and experimental design.

Paper #20 studies censoring procedures for modified censoring of Type I, in a theoretical manner. These modifications are of the same type that were done for Type II and studied in the previous years under this series of grants. These results are to say the least, very important.

Paper #21 studies the question of obtaining orthogonal designs in which the set of nonnegligible parameters is any given set of parameters.

Paper #22 obtains some results on the theory of optimal designs, where we add or delete a flat to a given orthogonal array.

Paper #23 studies probing designs for the 2^4 case.

Paper #24 considers the orthogonal main effects plans which were introduced by ADDELMAN, in which many authors have worked. This paper shows certain fundamental defects in this whole approach, and many errors in the work of all these authors.

Paper #25 studies a problem in the theory of search linear models, which is concerned with the probability that the nonnegligible parameters will be correctly identified.

Paper #26 contains the rudiments of some work which was begun in the field of the connection of design theory and signal processing.

V. Patents

There are no patents.